MEASUREMENT OF MARS DUST PARTICLE SIZE AND ELECTROSTATIC CHARGE DISTRIBUTIONS USING THE E-SPART ANALYZER.

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Introduction: There are strong indications that dust is of great importance on Mars. Dust appears to have both long-term effects on the surface geologic evolution as well as on the aeolian processes in the present climate conditions. Early spacecraft missions confirmed hypotheses from telescopic work that changes observed in the planet's surface markings are caused by wind-driven redistribution of dust [1, 2, 3]. Suspended dust is known to alter the atmospheric thermal structure and circulation as well as to obscure our ability for remote observation of the planet's surface, especially during the occasional development of larger, planet-encircling dust storms which occur on average once every three Martian years [4, 5].

Discussion and Conclusions: A direct measurement of the particle size distribution (PSD) has never been performed on Mars [6]. A popular model for the particle size distribution is a modified gamma function that assumes no variation as a function of latitude [7, 8]. This model made it possible to match the observations in both the visible and infrared intensity of airborne dust above the Viking Landers in 1977 using the same size distribution.

The instrument currently being developed to measure the electrostatic properties and particle-size distribution of Mars dust is an electrical single-particle aerodynamic relaxation time (E-SPART) analyzer [9], as shown in Figure 1.
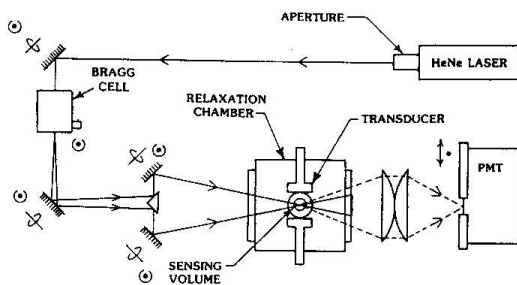

Figure 1. Diagram of the E-SPART analyzer showing the LDV optics and the relaxation chamber.

There are three basic components of the E-SPART analyzer: 1) a dual beam, frequency-biased laser Doppler velocimeter (LDV), 2) a relaxation cell, and 3) an electronic signal and data processing system. In the E-SPART analyzer, the LDV measures in a noninvasive way the particle velocity in its sensing volume. The sensing volume is located at the center of a relaxation chamber. The direction of the Mars dust particles flow is vertically downwards through the sensing volume. As the particles move downward, through the sensing volume, in the direction normal to the plane containing the two converging laser beams, it experiences AC electric excitation that causes the particles to oscillate in a horizontal direction parallel to the direction of LDV velocity measurements. The AC electric excitation is generated by using a pair of electrodes located inside the relaxation cell and positioned symmetrically across the LDV sensing volume. The electronic signal and data processor, analyze the phase lag ϕ of the particle motion with respect to the AC electric field driving the particle. The gas dynamic diameter d_a is derived from the value ϕ. The measurements of d_a and the direction and amplitude of the electrical migration velocity V_e of the particles with respect to the electric field provide the polarity and magnitude of electrical charge q of a particle. The horizontal sinusoidal particle motion $v_p(t)$ is given by the equation:

$$\tau_p \, dv_p/dt + v_p = E_o q \sin\omega t \,,$$

where τ_p is the aerodynamic relaxation time of the particle ω is the angular frequency of the electric field and E_o is the amplitude of the electric field. This equation has a steady state solution, which provides both d_a and q of particles.

An example of particle sampling of the JSC Mars-1 Martian Regolith Simulant [10] tribocharged against stainless steel beads for 10 minutes at 72° F with 44% relative humidity is shown in Figure 2. The simulant was ground down using a ball mill and measured with the E-SPART. The average diameter was 6.63 μm with a standard deviation of 1.91 μm. The total particle count was 5039 with a total mass of 3901.3 nanograms and total charge -311.02 femtoCoulombs. This gives a charge-to-mass ratio of -0.13 μC/g. The results are given in Figure 2 (a) as a three-dimensional view showing the number of particles versus the diameter and the percent of maximum charge, and in Figure 2 (b), the charge-to-mass ratio (Q/M) of positively and negatively charged particles as function of particle size.
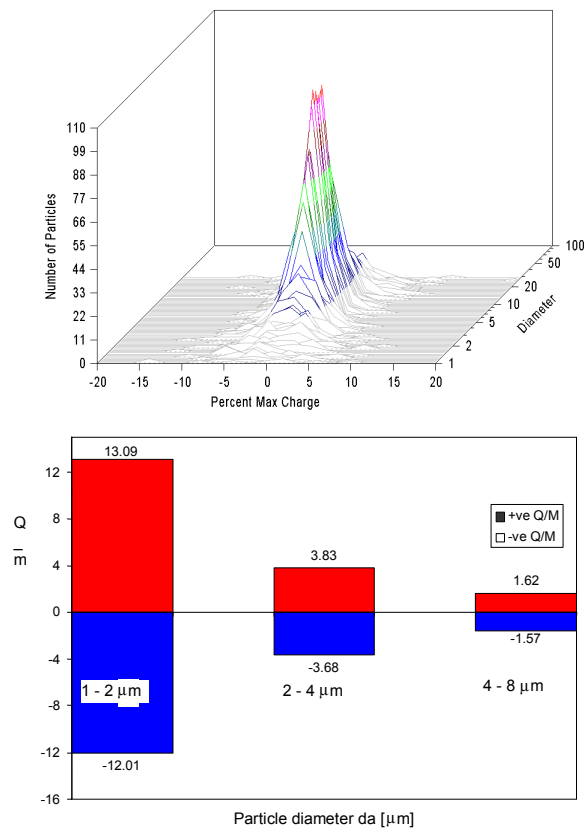
Figure 2. (a) The E-SPART results for JSC Mars-1 Martian simulant tribocharged against stainless steel beads for 10 minutes at 72° F with 44% relative humidity. (b) Charge-to-Mass ratio plotted as a function of the equivalent aerodynamic diameter (d_a) of dust particles tribocharged against stainless steel beads for 10 minutes

While the net charge-to-mass ratio (positive plus negative) for the Martian simulant dust in the size range 1 to 30 μm is –0.13 μC/g against stainless steel, the individual particles were found to be highly charged. For example, 1.06 μm diameter particles showed Q/M of –27.83 μC/g for negatively charged particles and +20.16 μC/g for positively charged particles.

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